PEM-Battery: Design, Construction, and Test

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Abstract

At present, the vast majority of electric utility substations throughout the United States utilize lead-acid battery banks as an emergency back-up power system/Uninterruptable Power System (UPS). A typical lead-acid battery back-up power system will provide about 1.25 kW of power for up to eight hours duration and costs a little under $25K over a fifteen year life cycle, with a significant portion of that cost allocated to maintenance. Any additional power or back-up time capability increases the overall costs linearly. Similar battery systems are also implemented for telecommunications back-up power applications with power requirements up to 6 kW. While reliability of the battery systems has been adequate, it would be beneficial to the users if the life cycle cost could be decreased and if the back-up operating time capability could be extended. But since the lead-acid battery technology is fully mature, there is little opportunity for cost reduction using lead-acid batteries.

Proton Exchange Membrane (PEM) fuel cells can be the lower cost, higher performance replacement to lead-acid batteries for back-up power applications. The simplest, most economical fuel cell stacks will operate on pure hydrogen and air, but the start-up times, on the order of several seconds, will be too slow for UPS applications. Hence, a hybrid fuel cell/capacitor system will provide the best alternative to lead-acid batteries for UPS applications. The fuel cell/capacitor hybrid system will eliminate the need for any batteries and will eliminate all battery maintenance requirements. The capacitor, like the battery, can be continuously trickle-charged until power delivery is needed. Immediately upon power outage, the capacitor will deliver the back-up power to the required electrical loads and the capacitor will supply the fuel cell start-up power. Once operating, the fuel cell can deliver uninterrupted power to the electrical loads and the capacitor can be idled. When grid power is restored, the fuel cell can be stopped and the capacitor can be automatically recharged and ready for the next power outage. The operating duration of the PEM Fuel Cell / Capacitor UPS system is simply a function of the amount of hydrogen stored with the system.

Power Computing Solutions, Inc. (PCS) is under contract to EPRI to design, fabricate and test a PEM fuel cell/capacitor hybrid power system for UPS applications. A fully functional 840 watt gross rated UPS system is the end item deliverable and testing will be conducted by PCS and by a third party selected by EPRI. A cost-effective approach is being taken to develop this first system whereby off-the-shelf components will be packaged in a neat but unoptimized manner, designed to allow for quick, easy modifications and implementation to actual field tests.

The fuel cell and capacitor are the two most important system components. A 100 cell H_2-air PEM fuel cell stack manufactured by De Nora will be the first stack tested in the UPS. This particular stack, with a nominal gross power rating of 840 watts at 70 volts, requires no reactant humidification, no liquid cooling loop, and allows for dead-ended H_2 operation. A 95 Farad, 56 volt ultracapacitor manufactured by Maxwell will be the first capacitor implemented. The system will be controlled using a Zworld BL1700 microcontroller and the UPS output power will be conditioned to provide 3-phase 110 volt to test loads for system demonstrations. The UPS can easily be configured for DC loads as well.

Design of the PEM Fuel Cell / Capacitor UPS system is complete and the capacitor subsystem has been successfully breadboarded and tested. Upon delivery of the fuel cell stack, the balance of the UPS will be fabricated, qualification tested, then delivered to the third party site designated by EPRI for further testing. Test results will be used to optimize the UPS design for specific applications. This first UPS system can also serve as a test platform for new components, particularly new fuel cell stacks and capacitors. In addition, it will be transportable with stand-alone operational capability so that actual field tests can be conducted with no major modifications.